

Analysis of Putting up Piles using Empirical Methods

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Abstract— Civil construction in Brazil has made great progress in recent decades, and it has become necessary to use in-depth studies of the resistance capacity of certain types of soils. The calculation methods unfortunately did not advance, the last ones were developed in the 1980s. The pile-type foundation in compliance with the settlement, presents a quick, economical solution and serves the distribution of loads in resistant soil very well, in addition to to be carried out with great depths. The present article has as general objective general objective to carry out the analysis of settlements in piles using empirical methods. In order to achieve the general objective, the following specific objectives are achieved: To carry out a theoretical survey; describe the types of settlement in piles using empirical methods; and to analyze the settlement in piles using empirical methods. A bibliographic review was carried out on the analysis of settlement in piles using empirical methods, emphasizing the empirical methods: Aoki-Velloso, the Décourt-Quaresma method and the Velloso method).

I. INTRODUCTION

In all construction works one must carefully pay close care for a stage of construction that is responsible for transmitting all the loads that will act in this building for layers of resistant soils, this stage being called foundation.

The foundation project is of fundamental importance in engineering, since it can compromise the entire structure supported to it. Given this, there is a whole process for choosing the type of foundation suitable for the desired project. This process takes into account aspects of the shape of the element for sizing, the weight of the structure that will be built on the foundation and the soil profile where the building will be executed.

For [1] the "isolated element of foundation" is nothing more than the component of the structure that transfers load to the soft part of the soil, in which it is usually the weak part. Thus, the soil a natural material, its behavior and resistance provide great variability, which makes the design of foundations unique for each work.

These days, the foundation technique has evolved a lot, but the purpose is the same. According to [2], the foundation is part of the process that transmits the

construction load to the ground by the base, tip resistance and its lateral surface or, still a combination of the two.

For the correct elaboration of a foundation project, it is necessary to carry out the forecast of load capacity assigned to the piles. The study of the load capacity of the cuttings can be developed from theoretical methods or by empirical methods.

Empirical methods is nothing more than the application of a safety factor in soil rupture stress, in order to reduce its resistance, the safety factor varies according to soil situations, however this factor varies between 2 to 3[3].

The recalque, in turn, differs according to the sturdy plane composed by the tip of the piles within the geotechnical massif, which was defined in design. In the case of continuous helix piles, the recals depend on the deformation of the massif that surrounds the piles, the deformation of the materials that make up the structural element of the piles, and their dimensions.

According to [4], it is possible to indicate three types of refills due to static loads: by elastic deformation, lateral flow and densification.

The present work has as general objective to perform the

analysis of recalques in cuttings using empirical methods. To achieve the general objective, the following specific objectives are: To carry out a theoretical survey; describe the types of recalques in cuttings using empirical methods; and to analyze the recalques in cuttings using empirical methods.

II. THEORETICAL FOUNDATION

2.1 SOIL CLASSIFICATION AND ANALYSIS

For [4], there are two main soil classification systems:

The Unified Classification System (U.S.C.), derived from the Airfield Classification System (A.C.), designed by A. Casagrande; The H.R.B. (Highway Research Board) classification, originated from the Public Roads Administration classification."

The author also divides the Unified Classification System into three major groups:

Coarse soils: these are those whose diameter of the absolute majority of grains is greater than 0,074 mm (more than 50% by weight of their grains, are retained in sieve nº.200). Fine soils: those whose diameter of the absolute majority of grains is less than 0,074 mm. Peats: highly organic soils, generalismente fibrillar and extremely compressible.

With regard to soil analysis [5], it establishes that it is necessary to obtain adequate knowledge of soils. It is necessary to identify and classify all the layers that make up the substrate to be analyzed, as well as its properties.

The determinations of substrate properties are analyzed through field tests, where those that stand out are [6]:

- The Standard Penetration Test - SPT;
- The Standard Penetration Test complemented with torque measurements - SPT-T;
- The cone penetration test - CPT;
- The cone penetration assay with measurement of neutral pressures, or piezocone - CPT-U;
- The vane test;
- Geophysical tests, in particular the Cross-Hole test..

2.1.1 STANDARD PENETRATION TEST – SPT

Percussion test probes are perforations capable of determining the depth of the water level and obtaining characteristics of different soil types. The hole is coated if unstable, otherwise it is uncoated, adding bentonite mud to the water. Drilling advances as the soil is removed with the help of a trépano and by water circulation.

Claims that percussion probing is a procedure that aswells soil resistance along the perforated depth, as it is

able to show the subsoil [6]. The SPT assay is standardized by [7], whose purposes are defined by it: "the determination of the type of soil according to the depths of occurrence; the position of the water level and the penetration resistance indexes (N) at each meter.

Standard Penetration Test (SPT) represented in Figure 4, the most widely used, the "sampler barrel" (fig.5), with 2" and 1 3/8" of external and internal diameters, respectively, and which opens longitudinally (for sample removal), is fixed at the end of the 45cm crimping rods on the ground, inside the probing tube. The crimping is made by a weight of 65kg, with 75cm of fall height. First, 15cm is penetrated and then the N number of blows applied to the other 30cm is recorded, annotating separately every 15cm [4].

According to [7], the determination of the penetration resistance index occurs by the number of strokes corresponding to 30cm of the sampler – standard, after the initial crimping of 15cm, using sisal rope to lift the standardized hammer.

2.2 DEEP FOUNDATIONS

According to [8], deep foundation is an element that transmits the load to the ground through its base, or by its lateral surface, or by combining the two. It must be seated at least 3 metres deep. For [8], deep foundations are of two types: piles and tubulões.

Piles: elements executed entirely by equipment or tool, without, at any stage of their execution, there is a person's descent. The materials used can be wood, steel, precast concrete, concrete molded on site or by its combination [8].

According to [8], the continuous helix type monitored piles are defined as:

Piles of reinforced concrete molded in loco, executed by means of the introduction, by rotation, of a continuous helical traffic in the ground, and injection of concrete by the central rod of the trough itself simultaneously with its removal, and the reinforcement is introduced after the concrete of the pile [8].

For [9], the use piles can be qualified as displacement and excavated piles. Where in the excavated piles are the continuous helix cuttings, type "Strauss" among others. Excavated piles are those executed "in situ" through the drilling of the ground by any process, with removal of material, with or without coating, with or without the use of stabilizing fluid [9].

According to [10], recalque is the modification of the soil when subjected to loads, causing movement in the foundation that, depending on the intensity, can result in serious damage to the structure.

When a foundation element moves vertically, an absolute

reload is configured. The difference between the absolute recalques of two elements of the foundation is called differential recalque. The differential repress imposes distortions on the structure that can lead to cracks [11].

The [8] establishes that in works where the most important loads are vertical, the measurement of the recalques is the fundamental resource for observing the behavior of the work. The standard adds that this measure aims to allow the comparison of measured values with calculated values, aiming at improving the methods of forecasting of recalques.

Nevertheless, [12] state that the Brazilian practice of foundations consists of performing control of recalques only in situations where problems are observed in buildings, such as cracks or cracks. They emphasize the importance of the measurement of the recalques since the beginning of construction as a quality control of the foundations.

In 1975, the first method of Brazil for the evaluation of cutting load capacity was born, elaborated [13]. From there, other methods were elaborated by different authors. According the methods of [13] and [14] are the most used by Brazilians to reach the load capacity of piles. They are considered semi-empirical, based on both theoretical aspects and correlations obtained from CPT and SPT assays, respectively.

2.2.1 AOKI AND VELLOSO METHOD (1975)

In the method proposed by [13], the tip limit stress and lateral friction of the cutting can be found from the values obtained through the results of static cone penetration tests, CPT, using Equations 2.6 and 2.7 and the coefficients F_1 and F_2 .

According to [15], the load capacity is scaled by the deduction of the unknowns of high-end resistance (R_p), and lateral resistance (R_l), as expressed in equation 01:

$$R_p = r_p \cdot A_p + U \cdot \sum_{i=1}^n (r_{li}) \cdot \Delta l \quad (\text{Eq:01})$$

where: r_p = Load capacity in the stake nesting quota (Mpa);

A_p = Tip cross section area (m²);

r_l = Lateral friction in each layer of soil (Mpa);

U = Perimeter of the cross section of the stet (m);

Δl = Layer height (m).

Says that the load capacity values in the settlement quota (r_p), and lateral friction in each layer of soil (r_l), is defined through equations 02 and 03 [15]. Equation 04 defines the total load capacity.

$$\text{SPT: } r_p = (k \cdot N_p) / F_1 \quad (\text{Eq:02})$$

$$\text{SPT: } r_l = (\alpha \cdot [k \cdot N]_{-1}) / F_2 \quad (\text{Eq: 03})$$

$$R = (k \cdot N_p) / F_1 \cdot A_p + U / F_2 \cdot \sum_{i=1}^n (\alpha \cdot K \cdot N_{(i)} \cdot \Delta l) \quad (\text{Eq: 04})$$

The parameters of F_1 and F_2 are arranged in the figure 1.

Tipos de estacas	F_1	F_2
Franki	2,5	5
Pré-moldadas	1,75	3,5
Escavada	3	6

Fig.1: Transformation coefficient F_1 and F_2 .

Source: [13] and [1]

The K and α coefficients are shown in the figure 2.

Tipos de solo	K(Mpa)	α (%)
Areia	1,00	1,40
Areia Siltosa	0,80	2,00
Areia Silto-argilosa	0,70	2,40
Areia argilosa	0,60	3,00
Areia Argilo-siltosa	0,50	2,80
Silte	0,40	3,00
Silte arenoso	0,55	2,20
Silte areano-argiloso	0,45	2,80
Silte argiloso	0,23	3,40
Silte argilo-arenoso	0,25	3,00
Argila	0,20	6,00
Argila arenosa	0,35	2,40
Argila areno-siltosa	0,30	2,80
Argila Siltosa	0,22	4,00
Argila silto-arenosa	0,33	3,00

Fig.2: Coefficient K and α .

Source: [15] and [1]

2.2.2 METHOD OF DÉCOURT AND LENT(1978).

According to [15], the load capacity (R), is determined by calculating the lateral resistance parameters (R_l) and cutting-edge (R_p) respectively expressed by the equation 05:

$$R_l = r_l \cdot S_l \quad e \quad R_p = r_p \cdot A_p \quad (\text{Eq:05})$$

In which: r_l = Lateral friction in each layer of soil (Mpa); S_l = Cutting length (m); r_p = Load capacity in the stake nesting quota (Mpa); A_p = Tip cross section area (m²).

Towards [15], Lateral friction resistance (r_l), is calculated by means of the average value of the SPT penetration resistance index along the SPT (N_l), being expressed by the equation 06:

$$r_l = 10 \cdot \frac{N_l}{3+1} \quad (\text{Eq:06})$$

According to [15], the calculation of the load capacity of the pile base (r_p), is estimated by the equation 07:

$$r_p = C \cdot N_p \quad (\text{Eq:07})$$

Where: N_p = Average SPT value at the base of the pile, above and below the foundation tip (Kpa);

C = Characteristic soil coefficient, sized according to figure

3 (Kpa).

Tipos de solo	C (kPa)
Argila	120
Silte Argiloso*	200
Silte arenoso*	250
Areia	400

* Alteração de rochas (solos Residuais)

Fig.3: Characteristic soil coefficient (C).

Source: [14]

Introduces factors (α) and (β), respectively in the tip and side resistance plots, resulting in the load capacity according to the equation 08 [16].

$$R = \alpha \cdot C \cdot N_p \cdot A_p + \beta \cdot 10 \cdot \frac{N_l}{3+1} \cdot U \cdot L \quad (\text{Eq:08})$$

In which: α and β = Factors depending on the type of pile and soil represented in tables 4 and 5 respectively.

Tipo de solo	Tipo de estacas				
	Escavadas em geral	Escavadas (bentonita)	Hélice contínua	Raiz	Injetada sob alta pressão
Argila	0,85	0,85	0,30*	0,85*	1,0*
Solo intermediários	0,60	0,60	0,30*	0,60*	1,0*
Areias	0,50	0,50	0,30*	0,50*	1,0*

* valores apenas orientativos diante do reduzido número de dados disponíveis

Fig.4: Factor values α depending on the type of pile and soil.

Source:[16]

Tipo de solo	Tipo de estacas				
	Escavadas em geral	Escavadas (bentonita)	Hélice contínua	Raiz	Injetada sob alta pressão
Argila	0,80*	0,90*	1,0*	1,5*	3,0*
Solo intermediários	0,65*	0,75*	1,0*	1,5*	3,0*
Areias	0,50*	0,60*	1,0*	1,5*	3,0*

* valores apenas orientativos diante do reduzido número de dados disponíveis

Fig.5: Factor values β depending on the type of pile and soil.

Source: [16]

2.2.3 VELLOSO (1981)

Says that the cutting edge resistance (R_p) and lateral resistance (R_l) are determined using equations 09 and 10 respectively. Finding the total load capacity through equation 11, the values of α , β and λ [15].

$$R_p = \alpha * \beta * q_c * A_p \quad (\text{Eq:09})$$

$$R_p = \alpha * \lambda * U * \Sigma(f_c * \Delta_l) \quad (\text{Eq:10})$$

$$R = R_l + R_p \quad (\text{Eq:11})$$

In which: α = Station execution factor (table 9); λ = Loading factor (table 9); β = Base dimension factor (table 9); U = Perimeter of the cross section of the steel (m);

A_p = Base cross-section area (m²);

Δ_l = Height of soil layer (m);

R = Total resistance (Mpa);

R_l = Lateral resistance (Mpa);

R_p = Cutting-edge resistance (Mpa).

	α	λ	β
Estacas escavadas	0,5	-	-
Estacas cravadas	1,0	-	-
Estacas comprimidas	-	1,0	$1,016 - 0,016 * \frac{D_b}{d_c} \geq 0,2$
Estacas tracionadas	-	0,7	$D_d = D_f$
d_c = Diâmetro da ponta do cone no CPT; D_b = Diâmetro da base; D_f = Diâmetro do fuste.			

Fig.6: Values of α , β and λ .

Source:[1]

According to [1] in the case of using ptS in this method, the correlations expressed in equations 12 and 13 are adopted, respectively.

$$q_c = \alpha * N^b \quad (\text{Eq:12})$$

$$f_c = \alpha * N^b \quad (\text{Eq:13})$$

In which: a, b, a' and b' are correlation parameters to be defined for the typical soils of the construction site, according to figure 7.

Solo	Ponta		Atrito	
	a (kPa)	b	a' (kPa)	b'
Areias sedimentares submersas (1)	600	1	5,0	1
Argilas sedimentares submersas (1)	250	1	6,3	1
Solos residuais de gnaiss areno – siltosos submersos (1)	500	1	8,5	1
Solos residuais de gnaiss silto – arenosos submersos	400 (1)	1 (1)	8,0 (1)	1 (1)
	470 (2)	0,96 (2)	12,1 (2)	0,74 (2)
(1) Dados obtidos na área da Refinaria de Duque de Caxias (RJ).				
(2) Dados obtidos na área da Açominas (MG).				

Fig.7: Approximate values of a, b a' and b'

Source: [1]

2.3 STATIC LOAD TEST TEST

Tends to provide information to describe its load x displacement conduct and evaluate its load capacity qualities. It applies to all stake typologies, regardless of the execution process [17].

According to [17], the execution process is initiated when you have a load application device composed of one or more hydraulic jacks powered by electric or manual

pumps acting against a stable reaction system.

Stresses that in the execution of the load test, the pile is loaded until rupture or at least up to twice the estimated value for its workload. Initially, a load of no more than 20% of the maximum expected load value is applied through a hydraulic pack and pump. A new load starts after the reset has been stabilized [17].

Ensures that even when the safety factor is not expected

to decrease, it is valuable that every work with more than 100 piles has at least a static load rating [18].

According to [17], the Static Load Proof test can be running debt with slow or fast loading. What differs are the load applied at each stage, and in slow loading it should not exceed 20% of the expected workload. In fast loading this percentage drops to 10%. The time maintained until displacement stabilization is 30 minutes at slow and 5 minutes in fast.

III. MATERIALS AND METHODS

The methods are nothing more than satisfactorily general techniques to turn common procedures to an area of science or to all sciences. In this stage will be addressed the methods that will serve to propose an excellent work, which will contribute to the performance of the research.

3.1 DESCRIPTIONS AND LOCATION

This study was carried out in the municipality of Gurupi state of Tocantins. It is located in the south of the state, on the banks of the BR-153 (Belém-Brasília Highway), 223 km from Palmas, the state capital, and 742 km from Brasília. It lies at the watershed between the Araguaia and Tocantins rivers, at a latitude 11°43'48" south and at a longitude 49°04'08" west, being at an altitude of 287 meters. Its estimated population in 2018 was 85,737.

The methodological procedures seek to guide the research work, defining the means used to achieve the main objectives of the research.

It should be emphasized that in all research it is fundamental to use scientific methodology, since these passes greater credibility of the work as stated by

"The scientific method wants to discover the reality of the facts and these when discovered must, in turn, guide the use of the method. Therefore, method is only a means of access; only intelligence and reflection discover what facts and phenomena really are [19]." The methodology teaches how to seek real truth in the face of facts that are still purely theoretical.

The research is classified as exploratory, because according to [20] "exploratory studies do not elaborate hypotheses to be tested at work, restricting themselves to defining objectives and seeking more information on a given subject of study".

Also, he says that this method "has the effect of a more precise research, or, still for the elaboration of hypotheses" Having other aspects, such as enabling the researcher to make a provisional survey of the phenomenon he wishes to study".

The proposal used the descriptive method that according,

"descriptive work seeks to cover general and broad aspects of a context, also give room for the explanation of the cause and effect relationships of phenomena"

In the research process, the bibliographic technique was used, because according to [21], "bibliographic research is the systematized study developed as a basis for material published in books, magazines, newspapers, electronic networks, that is, material accessible to the general public".

The bibliographic research allows the researcher to reach a wide and extensive range of information regarding the phenomenon studied, it is a research with global scope, since, with the advent of technological transformation, increasingly accessible, it is possible to obtain information about a particular subject from the four corners of the world.

The choice of this line of guide is due to the fact that they capture general or complex concepts in particular and specific data for a given cause, it is thus possible to have an idea of the whole. Other writers such as [22] define these methods in a more explanatory way as: the deductive method seeks to explain the content studied, while the inductive expands the zone of knowledge as studied.

The procedure performed was content analysis, an active reflection of all data obtained, to achieve a synthetic and objective result about the analysis of recalques in cuttings using empirical methods.

It was necessary to use qualitative analysis that, "Qualitative research can be characterized as an attempt to understand a detailed understanding of the meanings and situational characteristics presented by the interviewees, in a place of the production of quantitative measures of characteristics or behavior".

The content analysis will be based on the understanding of the entire bibliography raised, with the notes of the most important points related to the analysis of recalques in cuttings using empirical methods.

IV. RESULTS AND DISCUSSION

To start an analysis of recalques in piles should start a geotechnical study, analyzing the reports of field surveys, and from this point on the study of the geotechnical massif of the soil is initiated, which provided the knowledge of soil layers, NSPT indices, groundwater level, soil identification and geological formation.

Associated with the recognition of the subsoil and its properties, it is necessary to analyze the load plant in order to identify the loads of the building the evaluation of the magnitude of the pillars, thus the geometric part of the project was initiated.

The analysis of the load plant and the lease of the pillars has an important role for the choice of the foundation employed, because from the shape and dimensions of the pillars, together with the report, the choice of the type of foundation is made and also through it it was succeeded in identifying and positioning each column, according to the calculation of influence in the determination of the drilling hole. Soon after, the identification of the soil and the loads transmitted therein, one can define the type of foundation type.

Then, the type of foundation must be defined and with the probing report, the determination of the load capacity of the soil and the length of the foundation, it is possible to use the semi-empirical methods: [13],[14] and [2].

For calculation using the Aoki Velloso Method, there is a variation according to the type of soil existing in each layer, and F1 and F2 varying according to the type of station. Stated by Kurt Amann's thesis that in the Brazilian geotechnical environment there are two classifications for the semi-empirical methods the "conservatives" and the "against safety" and presents according to summaries of scientific articles demonstrating the paradigm of classification of semi-empirical methods, results already expected for certain types of soils, in relation to semi-empirical methods, it shows that for soils of the type clay sand, clay and lateritic silt, in the region of São Paulo, and young residual, in the region of Goiás, presented better response with the Aoki Velloso method, that is, more resistant soils, considering it more conservative [23].

Décourt-Lent method uses parameters that vary depending on the soil and the type of the cutting, in this case, root. The C coefficient used varies according to each soil type and is a parameter for the calculation of the tip resistance. The method takes into account the stress referring to lateral friction, the mean value of NSPT along the stet. Whereas the NSPT ceiling to be considered in lateral friction should not exceed 50.

Furthermore, for the tip resistance are used mean values of the NSPT of the base layer of the tip of the cutting, of the immediately anterior and immediately posterior layer, and a maximum of 20% of the permissible load can be supported by the tip of the pile, for excavated piles [8].

According to Wiliam Bertuzzi, who analyzed load capacity for cuttings in sandy soils, it was observed that the semi-empirical method of Décourt-Quaresma presents better results. And also, as Kurt Amann's thesis provides a summary of scientific technical articles to demonstrate the paradigm of classification of semi-empirical methods, Annex D, demonstrates in places such as Belém, sandy soil and root cutting the best method was Décourt Quaresma, considered the most conservative, and also had good results

such as: sandy sediment, lateritic, porous clay and sandy clay [23].

V. FINAL CONSIDERATIONS

Based on the analysis of the results of the study carried out it can be concluded that to calculate the load capacity, based on the load test, the Aoki Velloso method can be considered effective, as they present values close to those found in the results of the assay. Also in this scenario, it is concluded that the Décourt-Quaresma method presents much lower values, characterizing itself as the least recommended method, for punctual study, due to the type of soil.

In view of the analyses performed in this study and the evaluated context, the results allow us to conclude that when using semi-empirical methods of estimating the recalque, soil characteristics should be carefully evaluated, especially in cases where the parameters used by them are obtained through semi-empirical correlations.

However, it is proven the influence that a recalque analysis can have on a foundation. That is, for geotechnical dimensioning, depending on the method used to estimate displacement and the parameters taken into account, a designer may overestimate the geometric characteristics of a foundation, or compromise the integrity, functioning and stability of a structure.

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